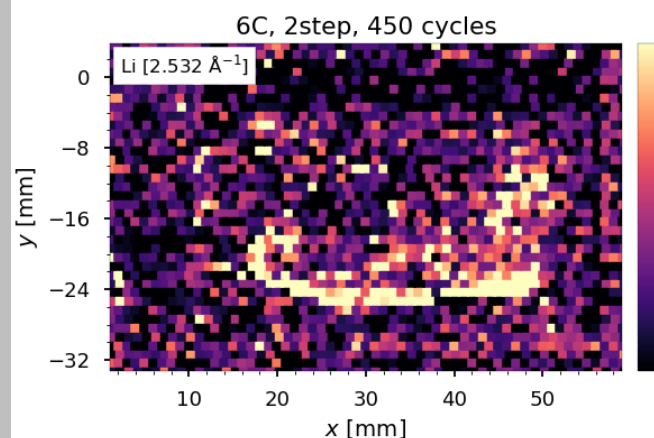


BAT 386



FAST CHARGE CELL EVALUATION OF LITHIUM-ION BATTERIES (XCEL): OVERVIEW



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Argonne National Lab

SAMUEL GILLARD
Department of Energy

This presentation does not contain any proprietary,
confidential, or otherwise restricted information

OVERVIEW

Timeline

- Start: October 1, 2017
- End: September 30, 2021
- Percent Complete: 75%

Budget

- Funding for FY20 – \$5.6M

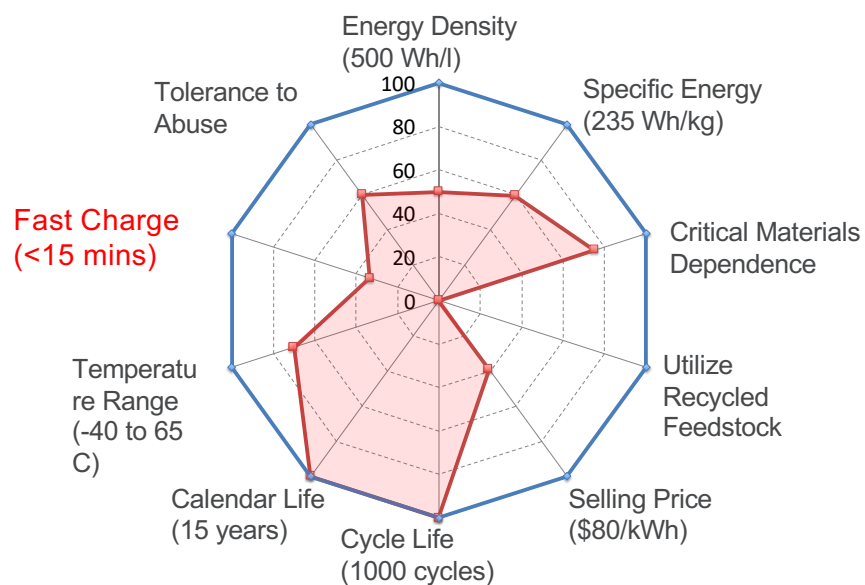
Barriers

- Cell degradation during fast charge
- Low energy density and high cost of fast charge cells

Partners

- Argonne National Laboratory
- Idaho National Laboratory
- Lawrence Berkeley National Lab
- National Renewable Energy Laboratory
- SLAC National Accelerator Lab
- Oak Ridge National Lab

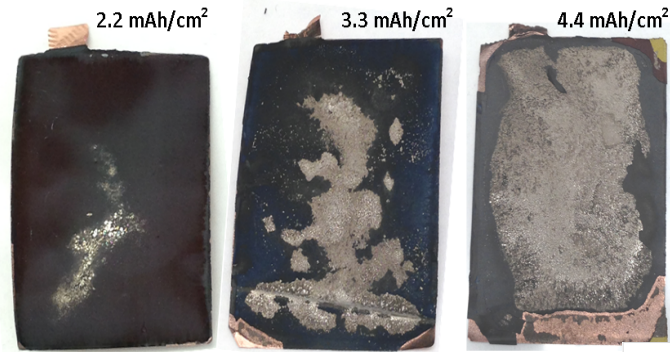
RELEVANCE: FAST CHARGE REMAINS AN ISSUE FOR WIDESPREAD ADOPTION OF EVS



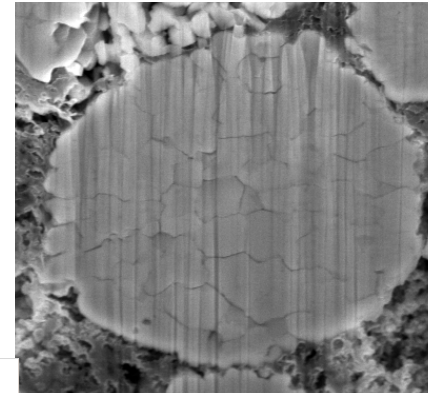
Fast charging a major issue. While fast charge cells exist, they are cost prohibitive or have poor life

RELEVANCE: WHAT LIMITS FAST CHARGE?

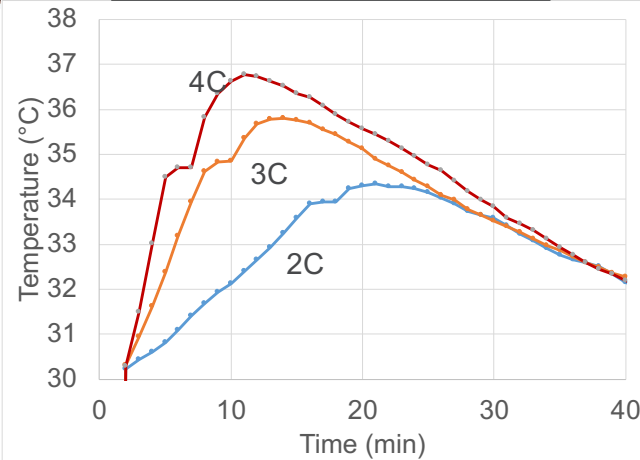
Li plating



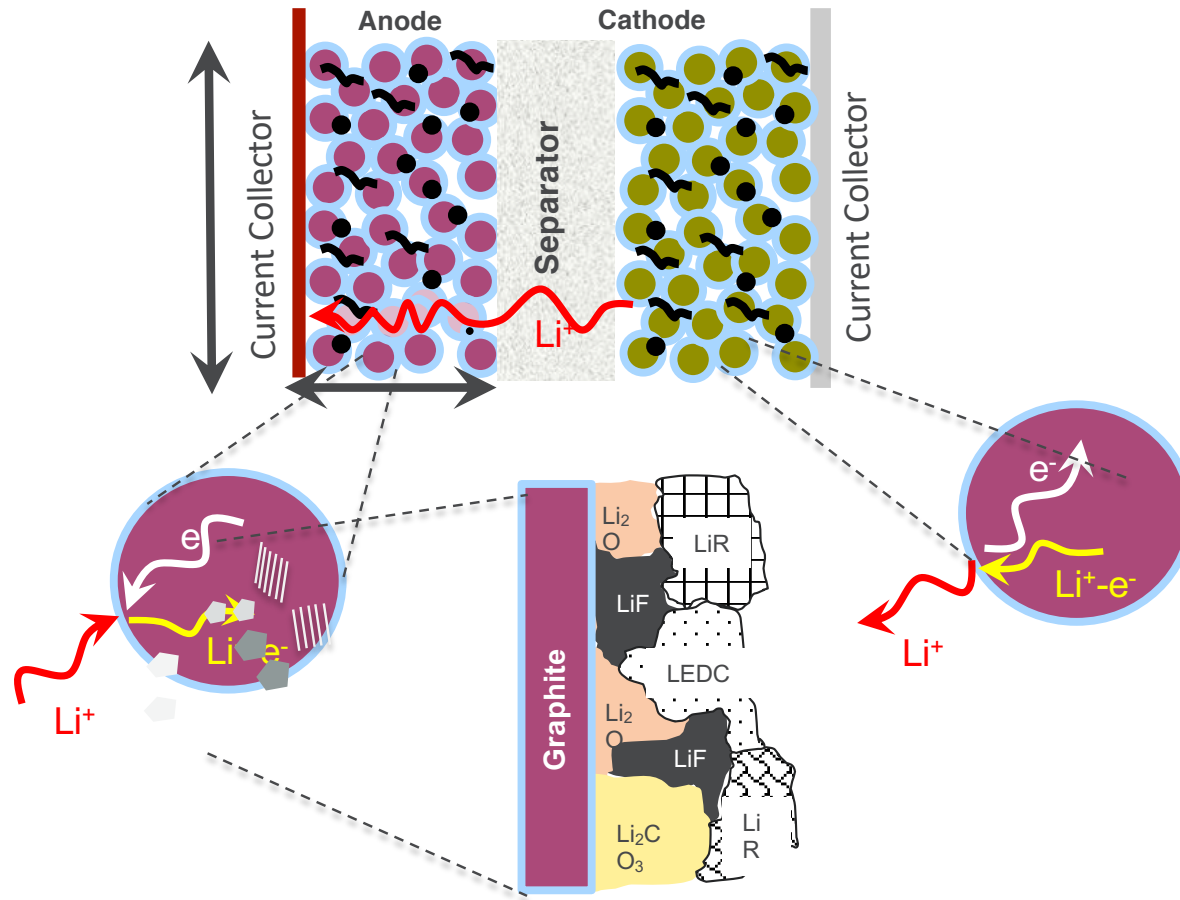
Particle breakup



Temperature rise



RELEVANCE: CHALLENGES AT MULTIPLE SCALES



COLLABORATION ACROSS LABS AND UNIVERSITIES



Cell and electrode design and building, performance characterization, post-test, cell and atomistic modeling, cost modeling



Li detection, electrode architecture, diagnostics



Performance characterization, failure analysis, electrolyte modeling and characterization, Li detection, charging protocols



Thermal characterization, life modeling, micro and macro scale modeling, electrolyte modeling and characterization



Li detection, novel separators, diagnostics



Detailed Li plating kinetic models, SEI modeling



6



CONTRIBUTORS AND ACKNOWLEDGEMENTS

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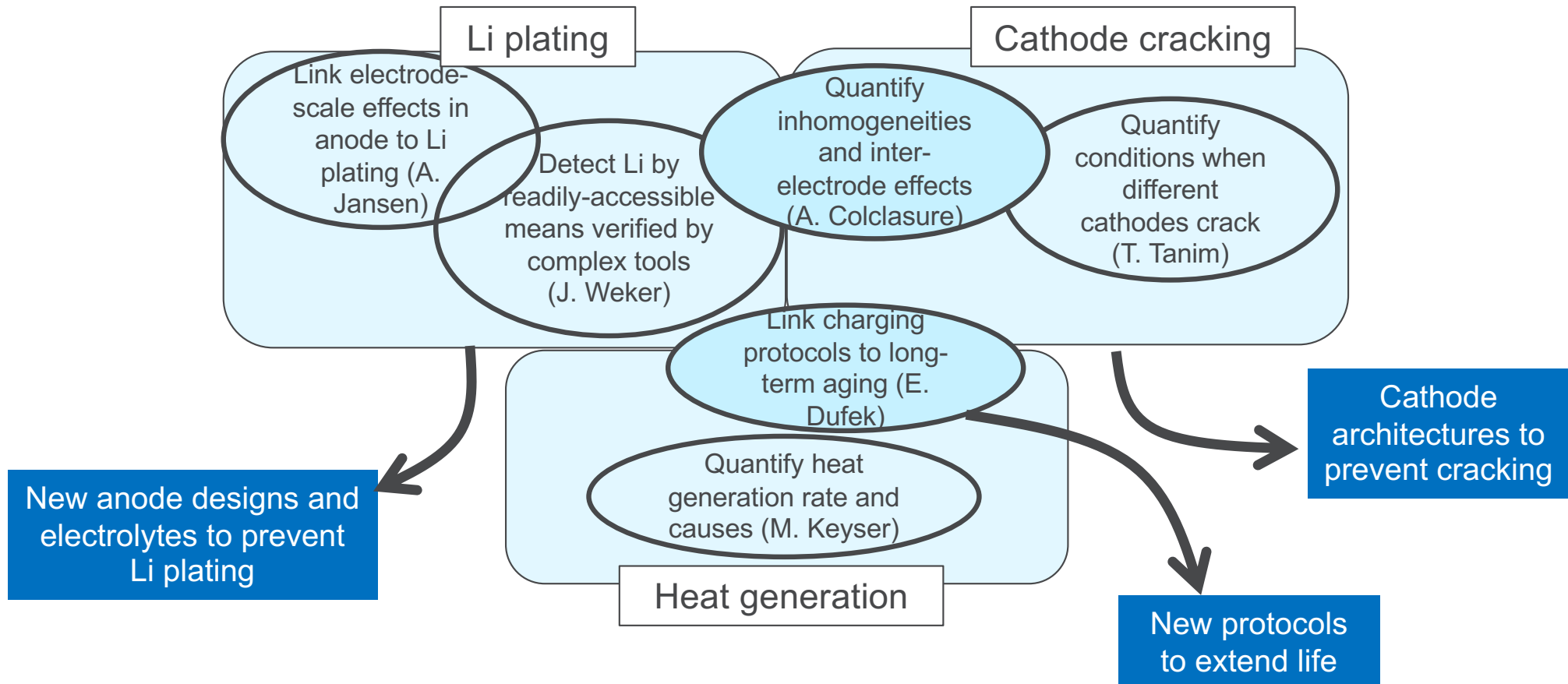
Argonne
NATIONAL LABORATORY



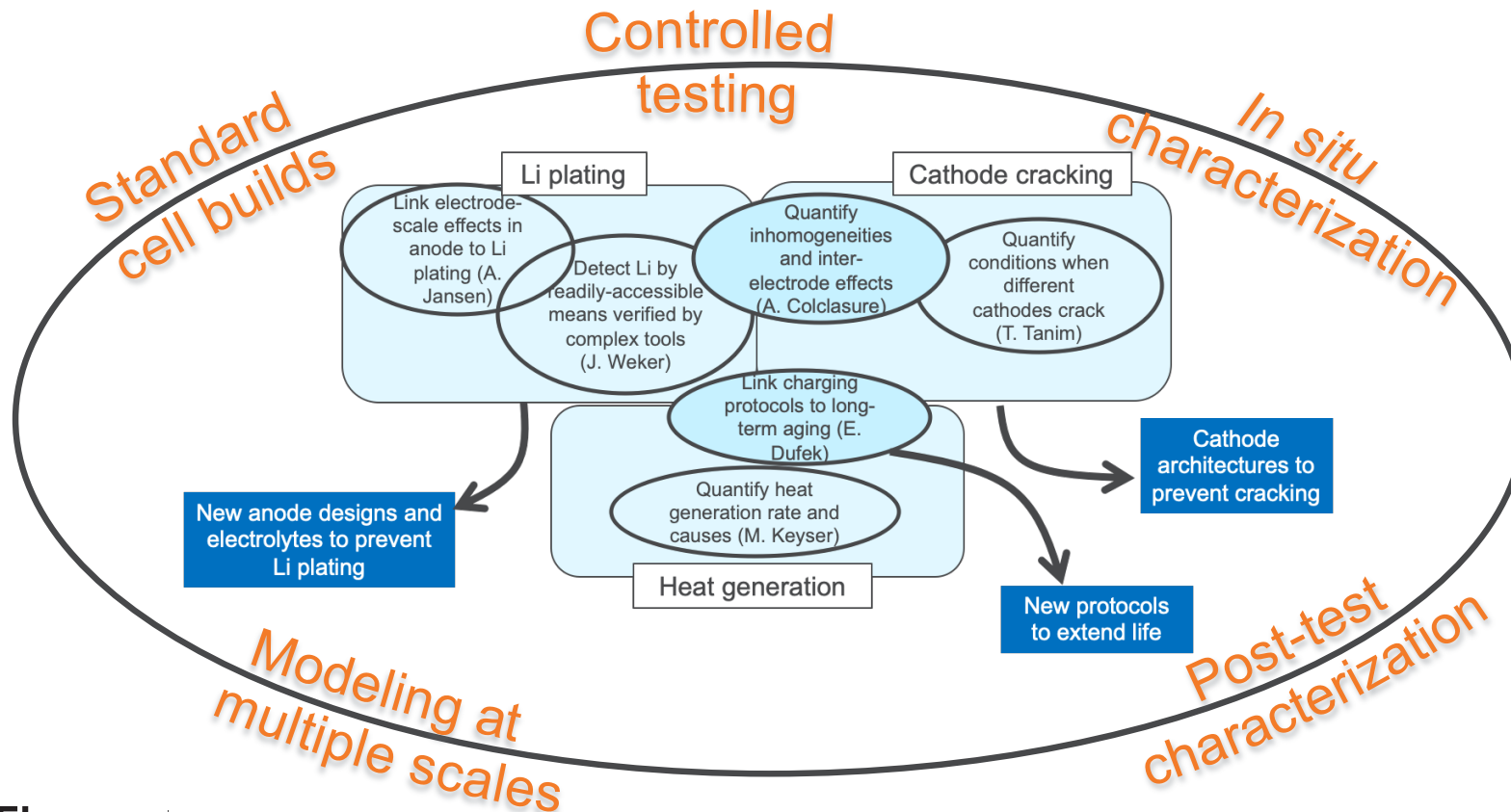
*Support for this work from the Vehicle Technologies Office,
DOE-EERE – Samuel Gillard, Steven Boyd, David Howell*



APPROACH: UNDERSTAND THE PROBLEM TO ENABLE SOLUTIONS



APPROACH COMBINES MULTIPLE EXPERTISE



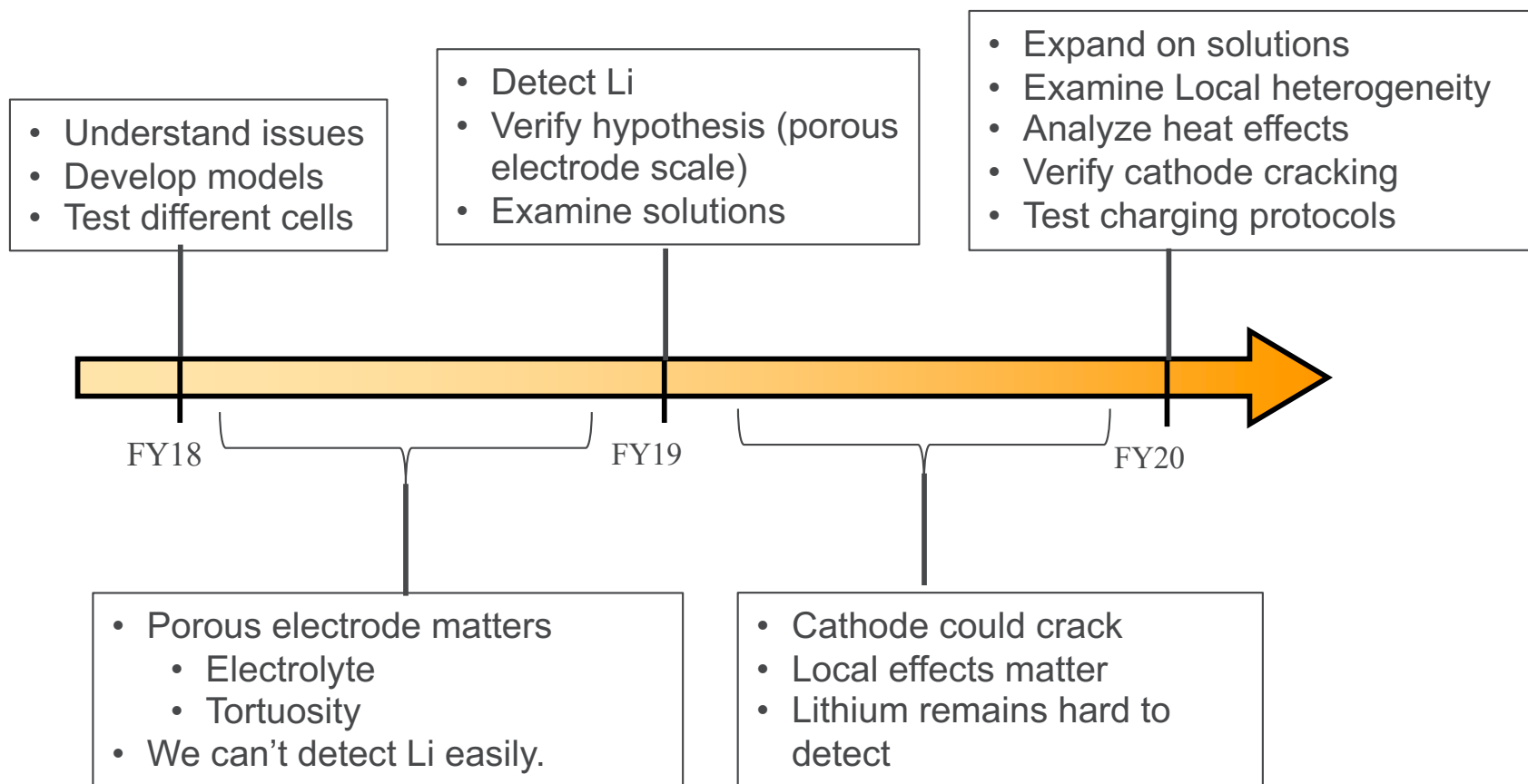
FY20 MILESTONES

- The program developed milestones for each Thrust
- Posters will show the milestones for each project.

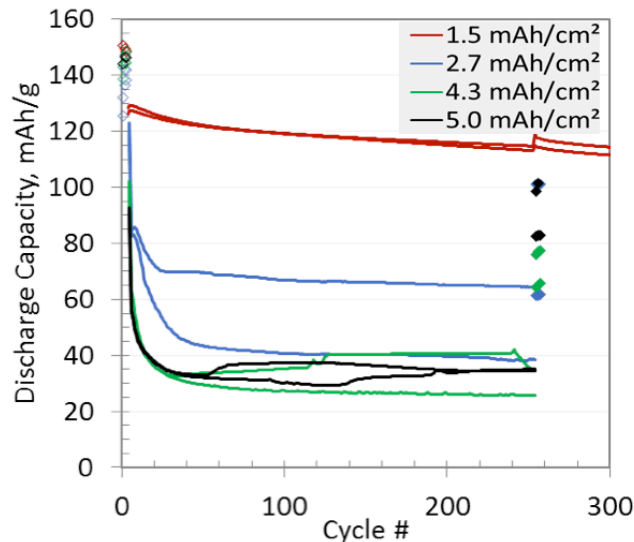
BY OCTOBER 2020 WE WILL HAVE...

1. Built and tested a “Hero” cell with best known anode design and electrolyte
2. Tested various hypothesis related to why Li plating is heterogeneous
3. Developed a table of different Li detection methods and their applicability
4. Determined conditions where cathodes crack
5. Developed strategies to mitigate excess heat during fast charge
6. Examined new charging protocols based on a model-based approach

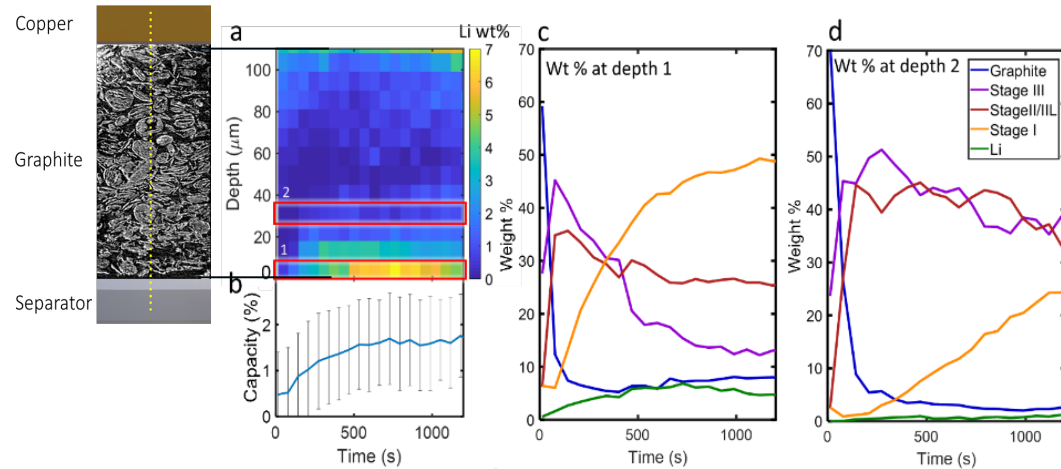
OVERALL TRAJECTORY OF THE PROJECT



WHAT DRIVES LI PLATING?



Increased loading
makes plating worse



- Li plates near separator (a) during charge
- Li plating only occurred when and where LiC_6 (Stage I) was present

Nonuniform reaction distribution in the anode drives lithium plating near the separator/anode interface

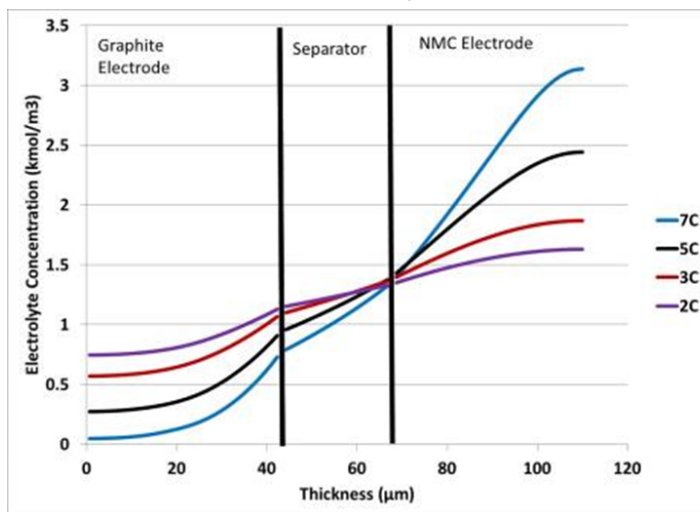
See BAT460

MODEL PROVIDES INSIGHTS INTO OBSERVATIONS

Low Electrode Loading

1.5 mAh/cm² cathode (42 μm)

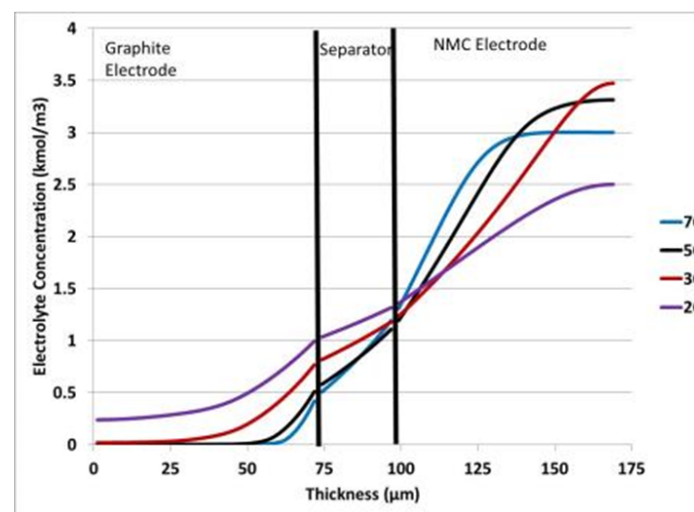
1.84 mAh/cm² anode (43 μm)



Medium Electrode Loading

2.5 mAh/cm² cathode (71 μm)

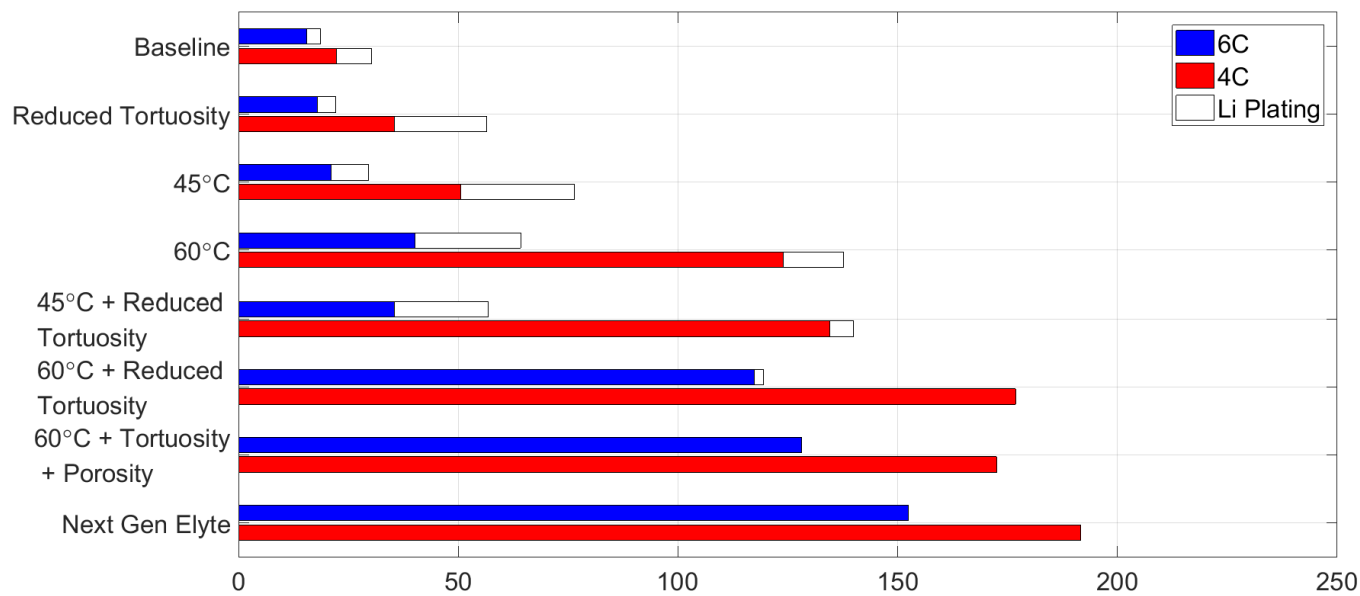
3.07 mAh/cm² anode (87 μm)



Fast charging will require enhancing the electrolyte transport in the porous electrode

MODELS SHOW IMPACT OF DIFFERENT APPROACHES

4 mAh/cm² (230 Wh/kg cell; 110 micron electrodes)

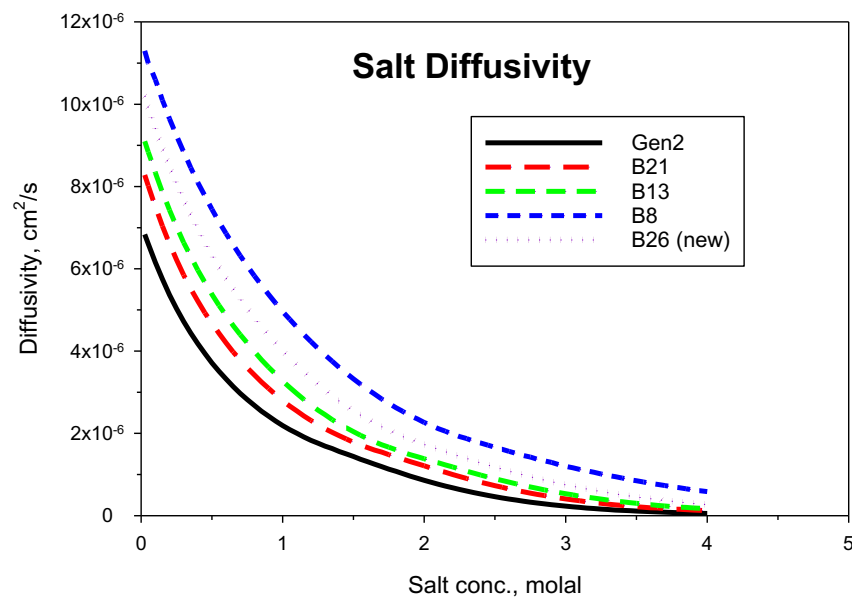


- Next Gen Electrolyte = 2X ionic conductivity, 4X diffusivity, and transference number increased by 0.15

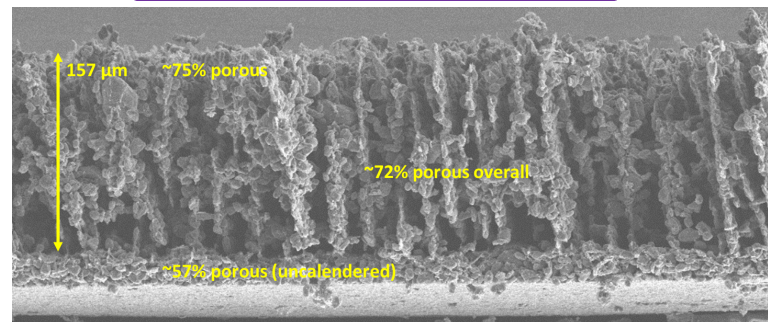
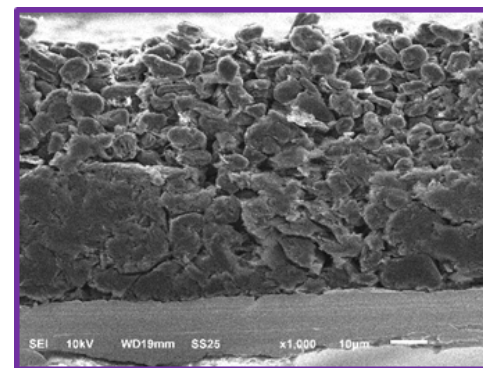
Need a combination of approaches

DIFFERENT SOLUTIONS BEING PURSUED

See BAT456



Higher transport property electrolytes

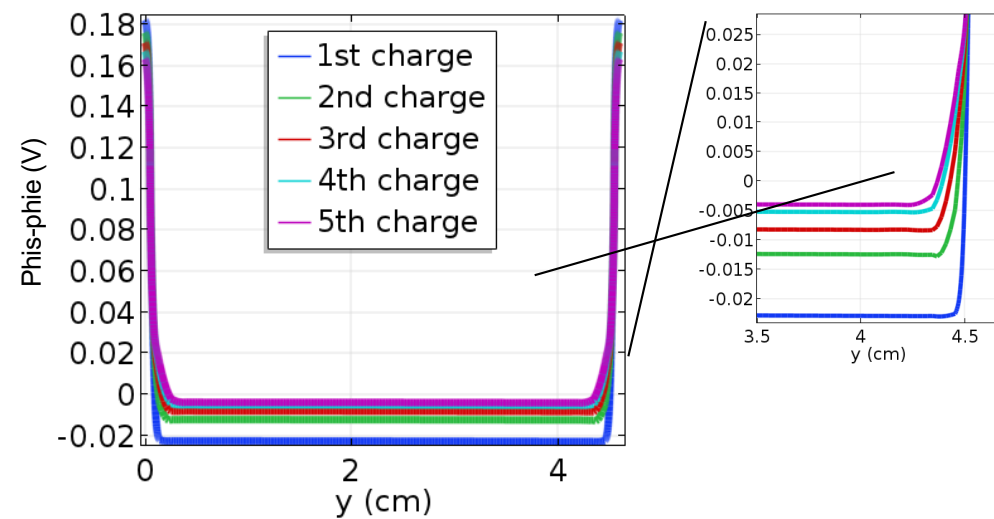
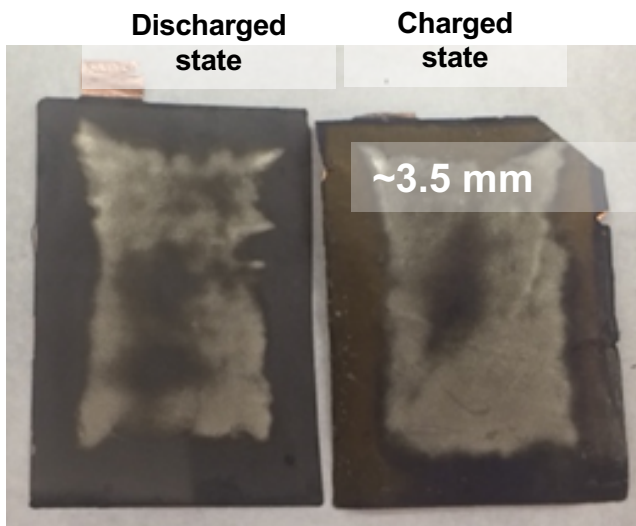


Anodes with controlled porosity/tortuosity

End of the year milestone is to test a “Hero” cell: best electrolyte/anode combination

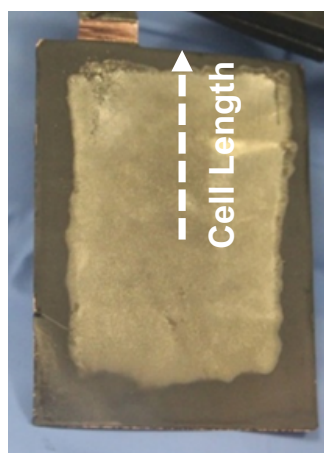
LI PLATING IS NOT UNIFORM ON THE SURFACE

See BAT461

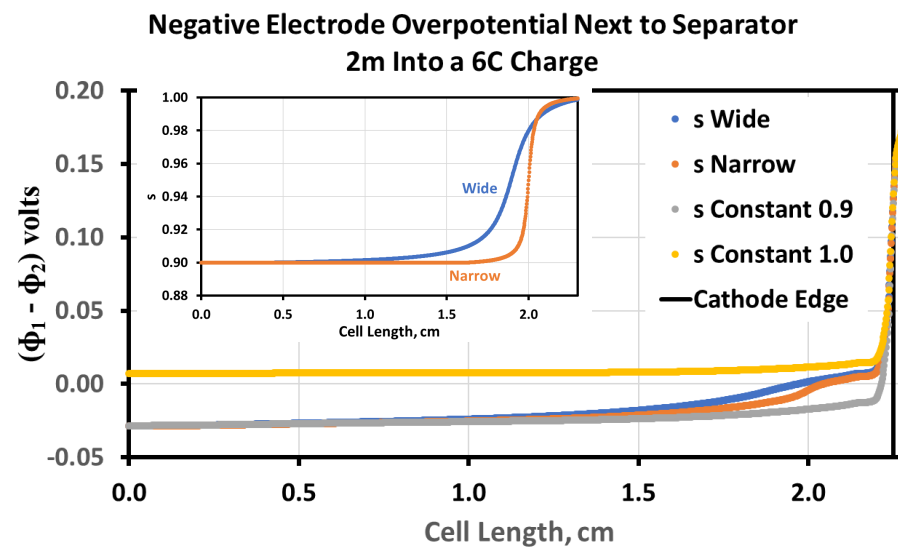
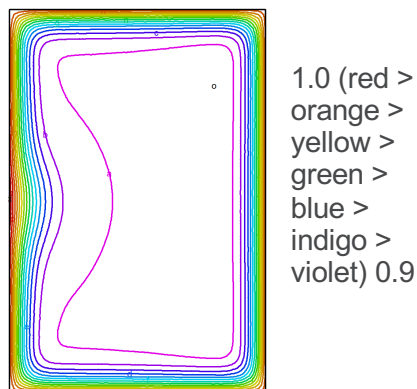


Edge effects partially explain the data (~2 mm)

EXAMINING IF ELECTROLYTE WETTING COULD ADD TO THIS PROBLEM



Saturation Distribution

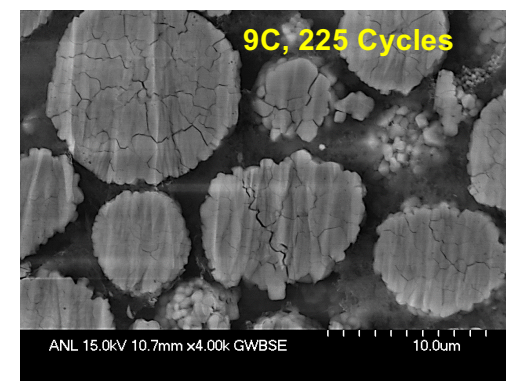
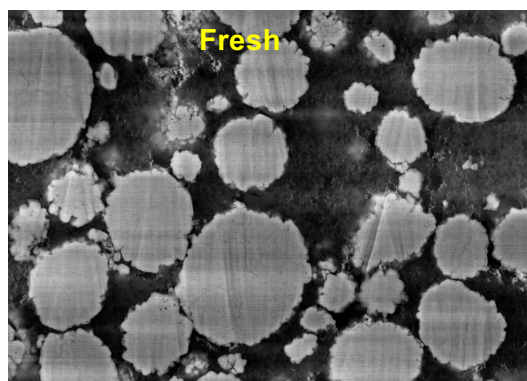
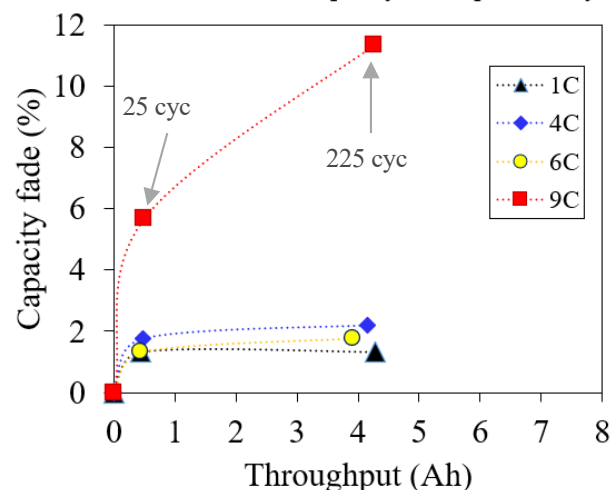


Model results consistent with the data. Experimental validation underway

WHEN DO CATHODES CRACK?

1.9 mAh/cm² anodes

Li/NMC532 half-cell capacity fade up to 225 cycles



- Li plating dominates <6 C
- Cathode cracking > 6C

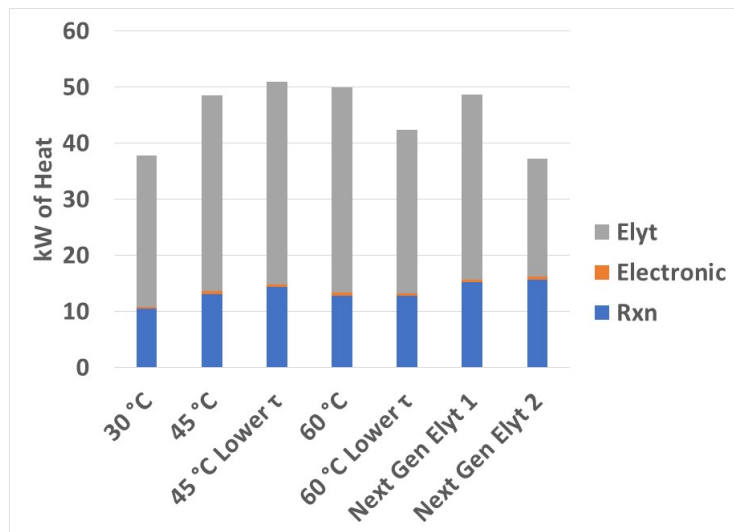
- SEM images show propensity for cracks after cycling

Program transitioning from 532 and examining 622 and 811 to determine cathode cracking conditions

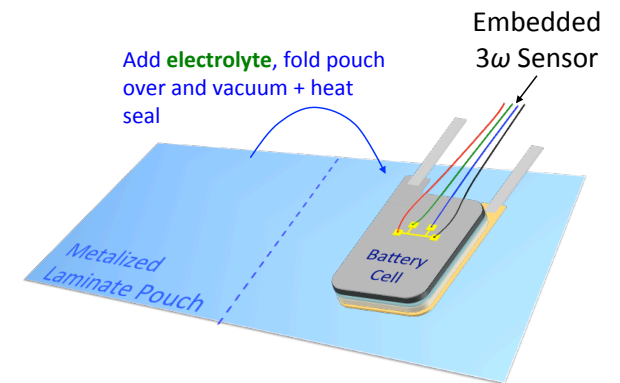
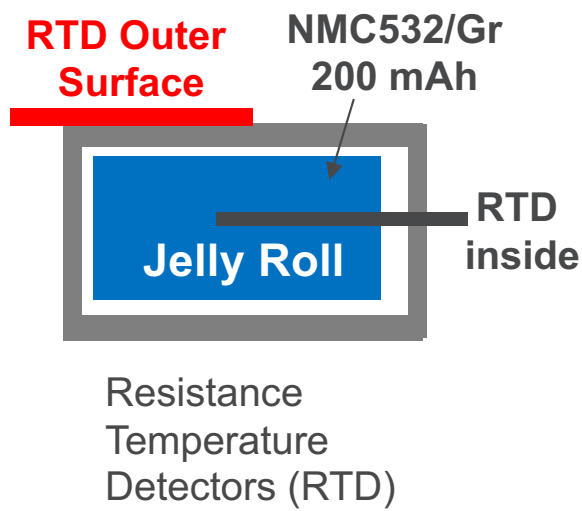
HEAT GENERATION REMAINS A CONCERN

See BAT459

100 kWh Pack Under
6C CCCV Charge



Dominant losses are from **electrolyte transport** followed by charge transfer reactions. The joule heating is minimal.

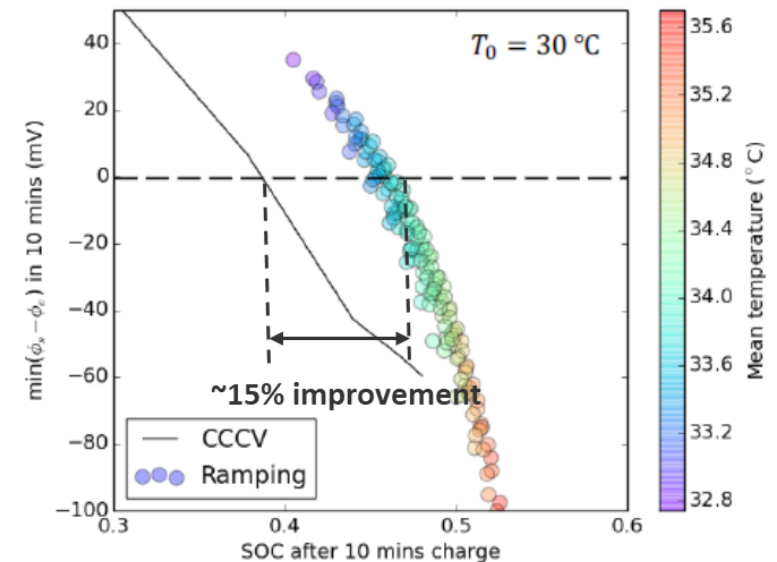
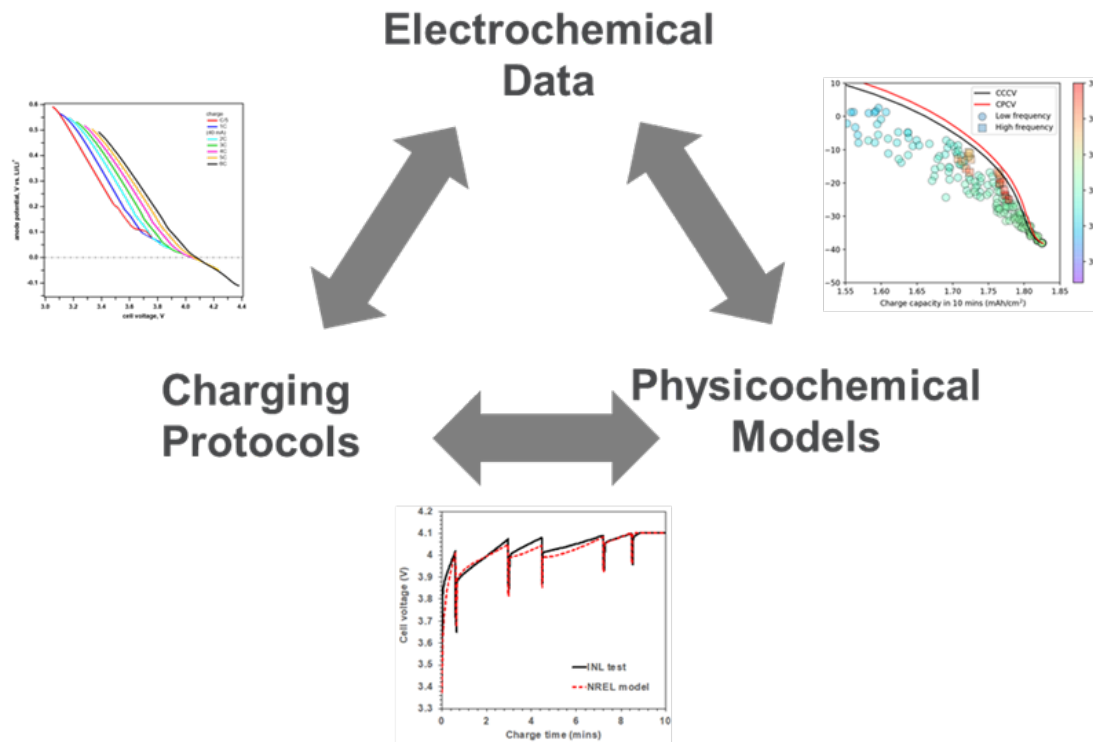


Sweep heating frequency to measure thermal properties at different distances

Temperature inhomogeneity is often hypothesized to be a culprit in observed inhomogeneous degradation

HOW DO CHARGING PROTOCOLS IMPACT FAST CHARGE?

See BAT462

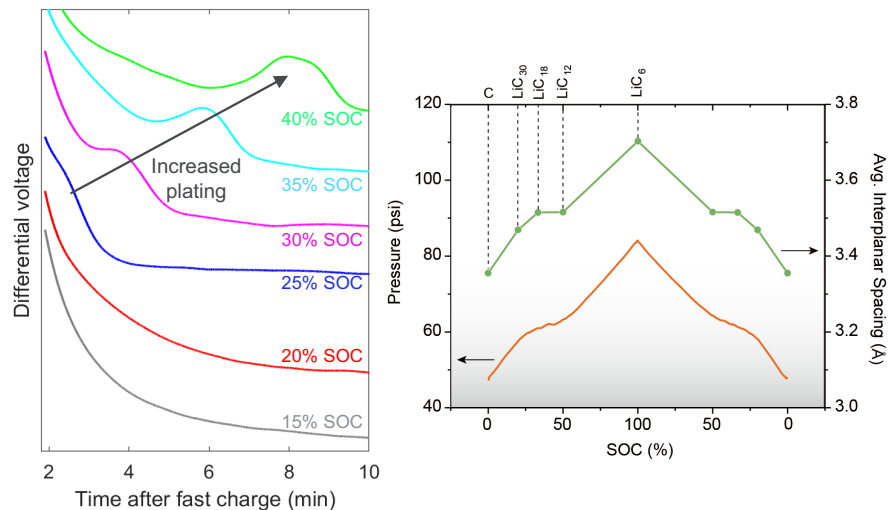


Model-informed protocols
show promise

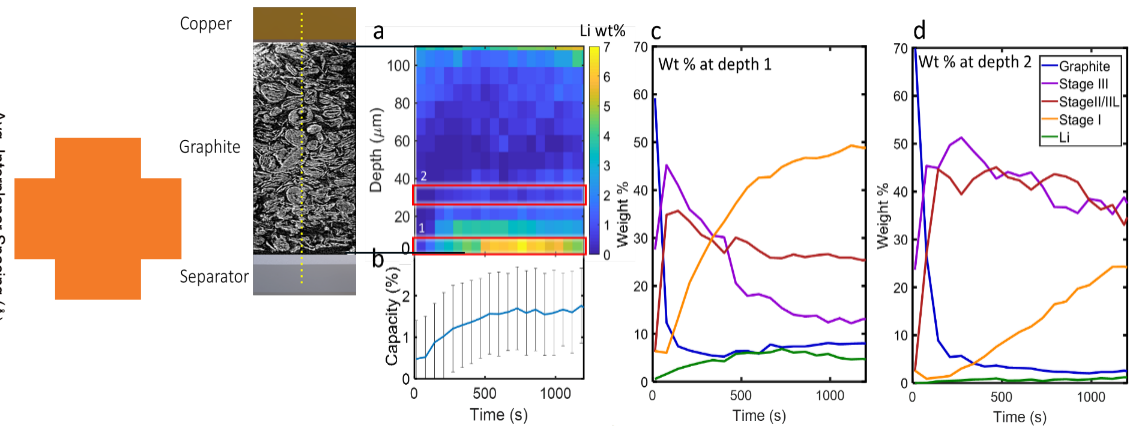
Evolving effort to help shed light into various processes during fast charge and ways to determine how they change with aging.

DETECTING LI PLATING WILL ENABLE BETTER CONTROL DURING OPERATION

See BAT 457
and 468



Real world implementable



Sophisticated methods to validate

We are examining the pros and cons of each approach so that different stakeholders (OEMs, academia) can pick appropriate technique

RESPONSE TO PREVIOUS YEAR REVIEWER'S COMMENTS

- “Consider adding anodes with small % of silicon”
 - DOE is examining status of Si. We will integrate this into the program as the anode performance improves.
- “Consider effect of temperature”
 - We have added a focus on this topic, with the aim of quantify the benefits and deleterious effects of temperature
- “Focus on the initial onset of plating and define experiments with a controlled anode potential”
 - We agree related to lithium plating and moving toward initial stages rather than extreme plating. Regarding planning experiments with controlled anode potential, we agree, but are limited by the inability of the models to correctly predict the onset of plating. Refernee electrodes are now routinely being used as a proxy

REMAINING CHALLENGES AND BARRIERS

1. Why does Li plating initiate at certain locations?
2. Do the "hero" anode and electrolyte result in similar life performance?
3. When is heat generation useful vs. detrimental?
4. Does cathode cracking become a big driver in higher Ni materials?
5. Can we establish the best readily-accessible technique for Li detection?
6. Can we design new charge protocols with consideration to the different failure models during fast charge?

PROPOSED FUTURE WORK

1. Why does Li plating initiate at certain locations?
2. Do the "hero" anode and electrolyte result in similar life performance?
3. When is heat generation useful vs. detrimental?
4. Does cathode cracking become a big driver in higher Ni materials?
5. Can we establish the best readily-accessible technique for Li detection?
6. Can we design new charge protocols with consideration to the different failure models during fast charge?

Aim is to answer these questions in the last year of the project

SUMMARY

